Overview

Executive Summary

Acoustic standards in the NASA-STD-3001 ensure an acceptable acoustic environment to

- preclude noise-related hearing loss
- preclude interference with communications
- support human performance

The NASA-STS-3001 Volume 2 acoustic standards are organized by mission phase due to the unique differences in noise levels and purposes of the standards. The **launch, entry, and landing phases** generate a great amount of noise caused by the combustion process in the rocket engines, engine jet-plume mixing, unsteady aerodynamic boundary-layer pressures, and fluctuating shockwaves. These phases also generate significant levels of infrasonic and ultrasonic acoustic energy. This short-term noise exposure normally does not exceed 5 minutes of continuous duration. The main focus of controlling noise during this phase of flight is on protection of crew hearing and preservation of critical communications capability.

During **on-orbit, lunar, or extraterrestrial planetary operations phases** when engines are inactive, the focus shifts from protecting crew hearing to ensuring adequate communications, alarm audibility, crew productivity, and habitability. Therefore, the maximum allowable sound levels are lower than those required for launch and entry.

Standards Overview:

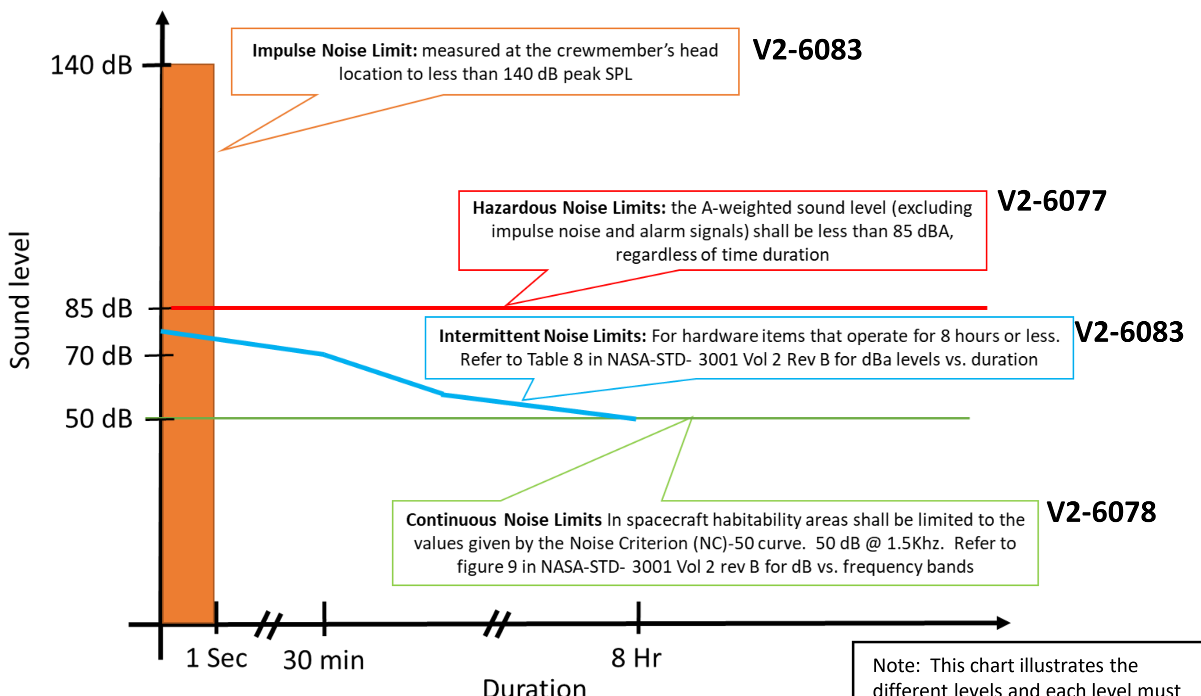
V2 6073: Launch, Entry, and Abort Noise Exposure Limits
V2 6074: Ceiling Limit for Launch and Entry
V2 6075: Ceiling Limit for Launch Abort
V2 6076: Launch, Entry, and Abort Impulse Noise Limits
V2 6077: Hazardous Noise Limits for All Phases Except Launch, Entry, and Abort
V2 6078: Continuous Noise Limits
V2 6079: Crew Sleep Continuous Noise Limits
V2 6080: Intermittent Noise Limits
V2 6081: Alarm Maximum Sound Level Limit
V2 6082: Annoyance Noise Limits for Crew Sleep
V2 6083: Impulse Noise Limit
V2 6084: Narrow-Band Noise Limits
V2 6085: Infrasonic Sound Pressure Limits
V2 6087: Acoustic Monitoring
V2 6088: Individual Noise Exposure Monitoring
V2 6106: Noise Limit for Personal Communication Devices

Background

Acoustic levels are measured in the decibel – dB.

- Frequency and time weighting is applied in the processing stage of sound measurement to make statistical descriptions of sound (e.g., peak or average level) and/or to make the measurements better correspond to human perception.
- Average Predicted risks of hearing damage are based on the noise source's level (typically reported in dBA) and duration of exposure.
  - **"A-weighting"** - dBa - compensates for the fact that the ear is comparatively less sensitive to lower and very high frequencies. Weighted between 1000 -5000Hz.
- **Sound pressure level** uses a logarithmic scale to represent the sound pressure of a sound relative to a reference pressure. The reference sound pressure is typically the threshold of human hearing: 2×10^{-5} Pa.

Noise Limits for On-Orbit Phase

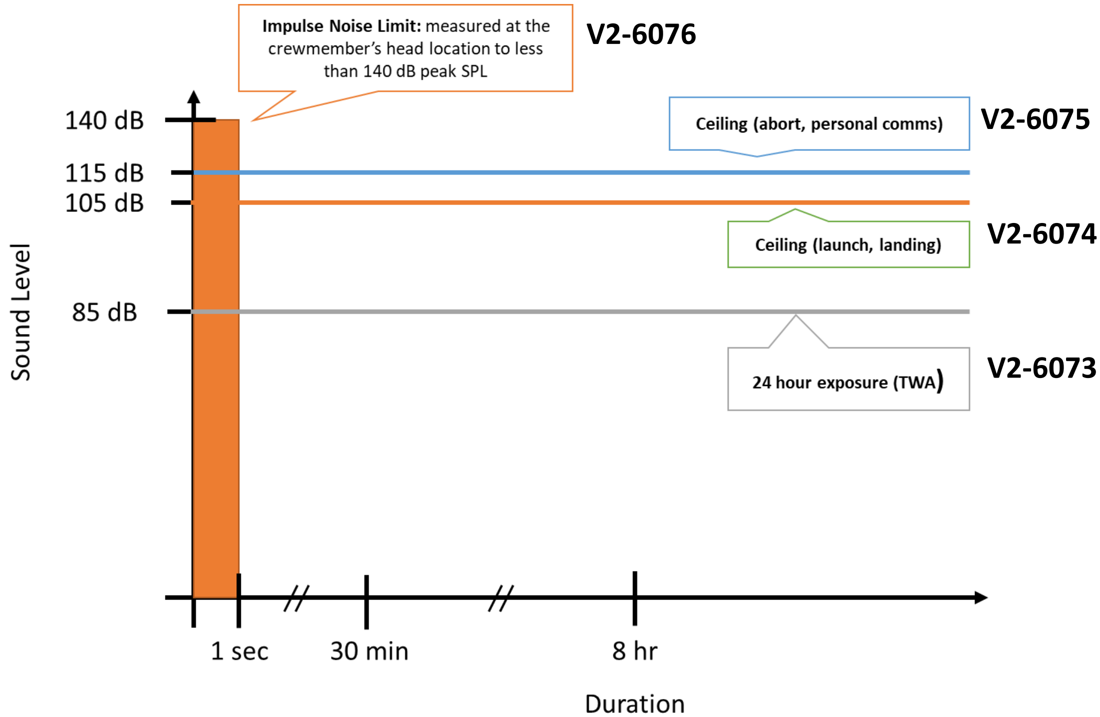


Note: This chart illustrates the different levels and each level must use the appropriate units/weighting.

- "Impulse" is defined as noises lasting shorter than one second.
- Intermittent limits are defined through durations up to 8 hours. For durations longer than 8 hours, the continuous limits take over.

Background

Noise Limits for Launch, Ascent, and Descent Phases



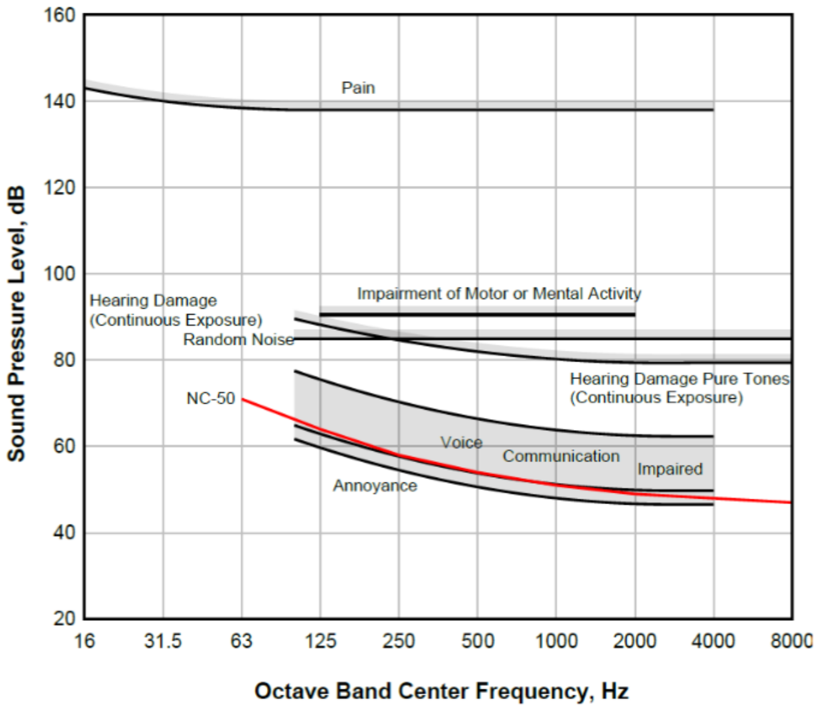
- "Impulse" is defined as noises lasting shorter than one second.

Risks

Noise exposure is generally considered to affect hearing, but it can also cause other physiological effects, (e.g. irritation, headaches, and degradation in sleep and relaxation). Noise can also affect performance of specific activities (e.g., working and speech communications). Even noise that the crew does not perceive as harmful may cause deleterious effects, as crews may become desensitized to elevated noise levels or not consider the noise to be objectionable (i.e., broad-band, ultrasonic, or infrasonic noise). Because of this insensitivity to sound pressure level changes, it is important to rely on quantitative noise measurements when designing hardware and verifying acoustic characteristics of space vehicles.

Reference Data

NASA/SP-2015-624 – ACOUSTICS AND NOISE CONTROL IN SPACE CREW COMPARTMENTS – *Goodman & Grosveld*



This graph shows sound limits for various conditions across audible frequencies. Note: Since the human ear is more sensitive to high frequencies the limits at higher frequencies are more stringent than lower frequencies.

The NC-50 curve in particular varies from 70 dB at 63Hz to 45 dB at 8 kHz.

Examples of issues with high sound levels in spacecraft

Sound levels in the Spacelab Module, a research module located in the Shuttle's cargo bay during STS-40, were measured to be 68 dBA, on a daily average basis, but rose on some days to be as high as 75.5 dBA and up to 84 dBA during ergometer operations (Goodman, 1991b). As a result, serious problems with communications, both with the ground and between crewmembers, were experienced. Communications capability within the Spacelab had become obscured by the high ambient noise levels of the experiment hardware, and the crew had to move into the airlock (away from the experiments they were operating) to communicate. Noise levels in the Orbiter Crew Module during STS-40 also were high, reaching daily averages as high as 71 to 73 dBA compared to 73.5 to 75.5 dBA in Spacelab. The crew was very irritated during operations and sleep periods, and had headaches due to the high noise levels experienced (Goodman, 1991a). This is an example of a mission of short duration (less than 30 days) in which high noise levels became a problem because of the resulting poor communications and habitability.

Reference Documents

NASA-Standard-3001 Volume 2, Revision B
International Space Station Acoustics—A Status Report

Application Notes

Monitoring

From “International Space Station—A Status Report:”

Acoustic monitoring is an important part of the noise control process on ISS, providing critical data for trend analysis, noise exposure analysis, validation of acoustic analysis and predictions, and to provide strong evidence for ensuring crew health and safety, thus allowing Flight Certification. To this purpose, sound level meter (SLM) measurements and acoustic noise dosimetry are routinely performed.

Design Guidance

Examples of design choices to mitigate noise exposure include:

- Low-noise fans
- Isolating vibrating equipment and components from crew members
- Cushioning loud equipment and components*
- Noise-dampening blankets and baffles*

*these materials are soft and porous, so special considerations must be taken vis-à-vis cleanliness and crew health concerns

Additionally

Regular maintenance of equipment and components helps reduce noise caused by off-nominal performance.

Hearing protection (earplugs, ear muffs, etc.) usually cannot be used to satisfy the requirements, as they pose a risk to crew comfort, health, performance, and communication.